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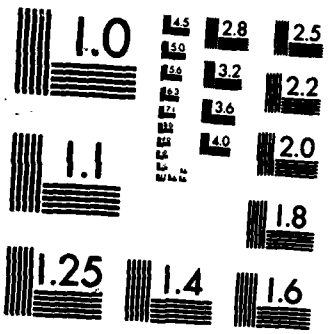

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research project investigated the nature of performance in highly practiced detection and recognition skills. We found that several tasks that were reputed to be automatic were susceptible to dual-task interference. Two separate limited-capacity systems were identified as important in these tasks. The first is a response system and the second is a modality-specific spatial attention system. The latter system is thought to be necessary for conjunciton of separable features such as color and form. Recent work on this contract shows, however, that at least some preattentive systems have access to conjunction information automatically.

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20. Future work should be directed at determining which feature conjunctions are present preattentively and which require spatial attention.

The Role of Attention in Automatic Skills

Final Report

James E. Hoffman

August 15, 1986

U.S. Army Research Office

Contract DAAG29-83-K-0049

University of Delaware

Statement of Problem

Acquisition of skill in a variety of cognitive and perceptual tasks takes place in three distinct stages. Early in practice, the skill is represented in a declarative format and performance is slow and attention-demanding. In the associative stage, the separate pieces of the skill become linked or associated. In the final, "autonomous" stage, the expert may not be aware of how the skill is accomplished and performance appears to be automatic. This final stage of skill development appears to be necessary for humans to effectively deal with the high information-load environments that are typical of pilots or air-controllers. This research project was designed to investigate the nature of automatic performance, in particular whether automatic skills are free of the requirement to investigate attention.

Summary of Results

Search and Detection

The approach we have taken is to train subjects on a particular skill until they reach some criterion of automaticity and then examine performance on that skill when it is combined with a second task. In earlier work, we found that a visual detection task meeting previously proposed criteria for being automatic was nonetheless susceptible to dual-task interference. This result indicates that some aspect of task performance is utilizing a limited-capacity system. Insight into the nature of this system was provided by examining the pattern of interference across a variety of different tasks. In general we found that interference was greater when both tasks occupied the same modality relative to different modalities. In addition, dual-task interference was greater with increases in the spatial separation between tasks.

This pattern of results is consistent with the claim that there are multiple processing resources that determine time-sharing performance. One important resource is a visual, spatial attention system that has a limited extent in the visual field. Information falling within a single "spotlight of attention" can be processed in parallel whereas information that is spatially separated must be dealt with by shifting the focus of attention from one location to another (see Hoffman, 1986 for a review).

Event-related Potentials

Some confirming evidence on this view was provided by Hoffman, Houck, MacMillan, Simons, and Oatman (1985) who used the P300 measure of the event-related potential to explore two additional issues. In previous studies examining dual-task performance in CM search tasks (Hoffman, Nelson, and Houck, 1983), two distinct kinds of interference could be discerned. Detection latency for CM targets suffered large delays in dual-task combinations. The magnitude of this interference was relatively independent of the spatial proximity of the two tasks and even whether or not they were in the same modality (Hoffman and Nelson, 1981). Detection accuracy, however, was highly dependent on the extent to which both tasks had simultaneous access to a spatial attention mechanism. This pattern suggests that the response

system is dependent on a limited-capacity resource that is sensitive to demands from a wide variety of disparate tasks. In contrast, detection accuracy reflects the operation of earlier stages that are modality-specific and dependent on spatial attention.

This characterization was tested by recording P300s in dual-task conditions with spatially separated tasks. To the extent that response latency and P300 latency reflect different limited-capacity systems, they might show a dissociation with variations in attention. This prediction follows from the claim that P300 latency is insensitive to factors that affect the response system. In contrast, P300 amplitude for each task should faithfully reflect the trade-off in accuracy of performance that occurs in dual-task conditions. These predictions were confirmed. Response latency for detecting CM targets increased dramatically as attention was withdrawn from the search task and allocated to the companion task. P300 latency increased by an amount that was an order of magnitude smaller. In addition, CM response latency increased continuously with reductions in attention to the CM task while P300 latency increased by the same amount in all dual-task conditions regardless of the specific allocation of attention between tasks.

P300 amplitude for the two tasks traded off in a linear fashion that closely mirrored the trade-off in performance under the same conditions. This result shows that the large P300s in CM detection obtained by Hoffman et. al. (1983) do not result from subjects "wasting resources" on this task. Instead, withdrawal of resources from the CM task results in a decrease in accuracy that is reflected in P300 amplitude. In addition, there is a large increase in overt detection latency that appears to reflect response level interference. We conclude, therefore, that there is evidence for both late and early selection. Overt responses represent a final output path for many tasks. Cross-talk interference may impose a serial structure at this level that is reflected in large increases in latency under dual-task conditions. Spatial attention reflects an "early" resource that is important in shape discrimination, even when such shapes are highly familiar resulting in rapid classification.

Semantic Priming

The other principal task that has been characterized as being automatic is semantic priming. In a lexical decision task, subjects are required to decide whether or not a letter string is a word. When this string is preceded by a semantically-related word (doctor-nurse), decision time is faster than if it is preceded by an unrelated word (chair-nurse). There are a variety of reasons for supposing that this process is automatic (summarized in Hoffman, 1987). Hoffman and MacMillan (1985) were interested in the question of whether semantic priming is influenced by the locus of visual attention. They found that little or no semantic priming was obtained for words presented in unattended visual areas. These results agree with other recent reports that indicate that even identity priming, in which a stimulus primes itself, can be influenced by spatial attention.

Feature-integration Theory

The feature integration theory proposed by Anne Treisman (Treisman and Gelade, 1980) provides one rationale for our findings that spatial attention is important even for well-practiced tasks. It holds that only "simple" features such as color, line orientation, and so on can be extracted in early vision (see Julesz and Bergen, 1983 for an alternative view on the features processed in early vision).

Conjunctions of these attributes can be discovered only by focusing an attentional spotlight of limited spatial extent on a specific area of visual space. This theory is consistent with most of the research reviewed previously. It would explain, for example, why consistent-mapping training might not be sufficient to eliminate the need for spatial attention (Hoffman, Nelson, and Houck, 1983). Targets and distractors might have been discriminable only in terms of a conjunction of attributes and the available evidence indicates that training cannot produce conjunction detectors, at least for color and form (Treisman and Gelade, 1980).

Houck and Hoffman (1986) recently employed a perceptual aftereffect (the McCollough effect) to investigate whether separable features are conjoined in preattentive vision. The McCollough effect is produced by having an observer adapt to an alternating sequence of, for example, red-vertical and green-horizontal bars. Following adaptation, black and white vertical bars will appear to be a desaturated green and horizontal black and white bars will appear pink. This is a conjunction adaptation effect because it depends on a particular combination of color and shape (line orientation). Given the substantial evidence that color and shape are separable attributes in search and texture segregation paradigms (Treisman and Gelade, 1980), these two dimensions should require spatial attention in order to be integrated. If this integration mechanism precedes the site responsible for adaptation then McCollough aftereffects should not occur for adaptation gratings presented outside the focus of attention. This is the prediction tested by Houck and Hoffman (1986).

The principal result was that the strength of the McCollough aftereffect was completely independent of spatial attention showing that at least some preattentive mechanism has access to conjunctions. In contrast, searching for these same patterns did require attention. These results show that different paradigms will provide different characterizations of the nature of preattentive vision. Future research of this kind should clarify what kinds of conjunctions are available preattentively and the precise role of spatial attention in feature integration.

Summary

This research project investigated the nature of performance in highly practiced detection and recognition skills. We found that several tasks that were reputed to bé automatic were susceptible to dual-task interference. Two separate limited-capacity systems were identified as important in these tasks. The first is a response system and the second is a modality-specific spatial attention system. The latter system is thought to be necessary for conjunction of separable features such as color and form. Recent work on this contract shows, however, that at least some preattentive systems have access to conjunction information automatically. Future work should be directed at determining which feature conjunctions are present preattentively and which require spatial attention.

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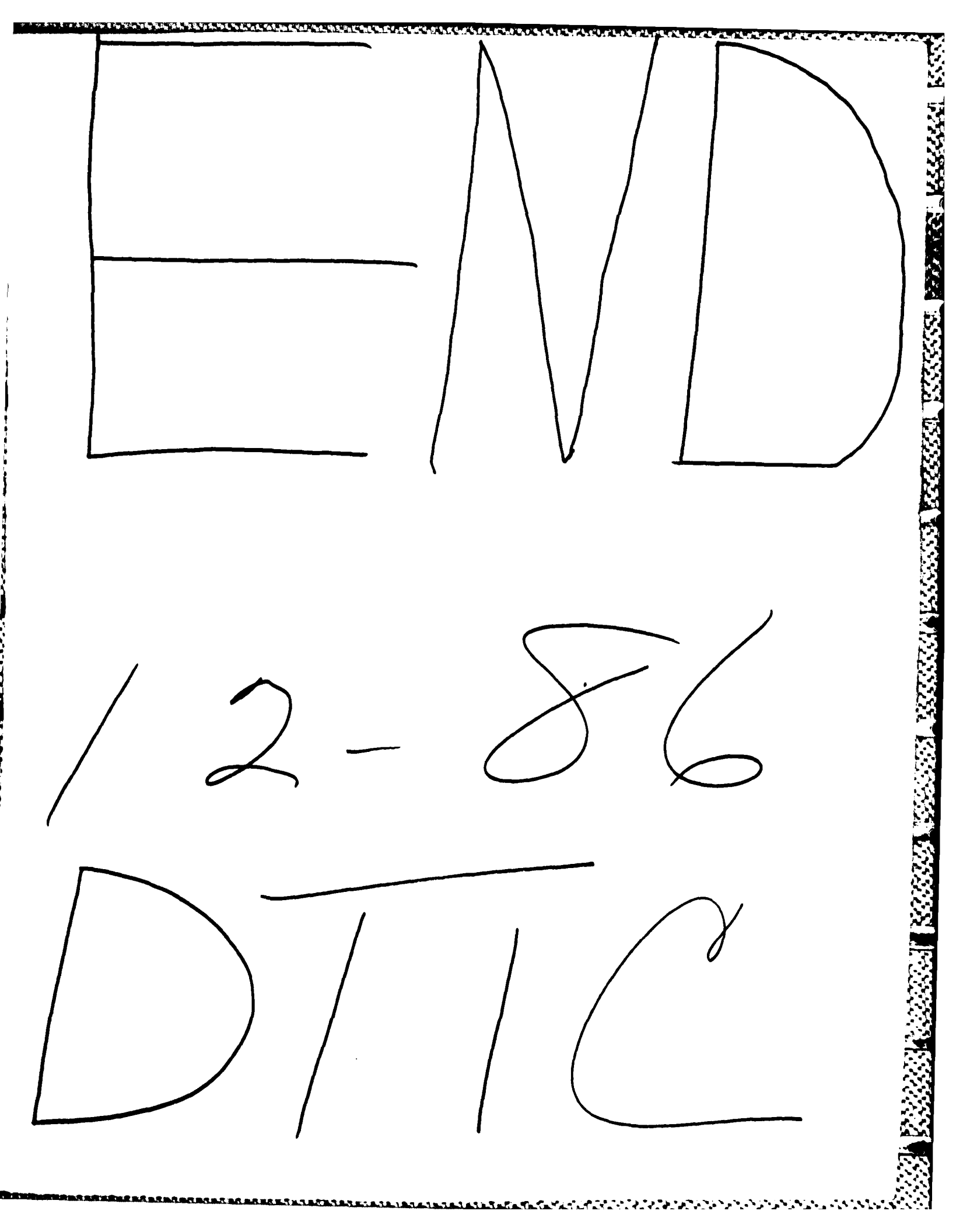
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